Performance of a Folded Dipole with a Closed Loop for RFID Applications

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Abstract—Folded dipoles are commonly used in the RFID applications. In this paper, we propose an RFID tag design using a folded dipole with a closed loop structure. The closed loop makes impedance matching design more easily especially when the small resistance and large reactance of the antenna impedance are required. Design methodology, simulation and performance measurement results of an implementation are also presented in this paper.

1. INTRODUCTION
Radio Frequency Identification (RFID) is a technology used for object identification and has become very popular in retail, transportation, manufacturing and supply chain [1]. An RFID system is composed of tags, one or more readers and a data management system. A tag consists of an antenna and an Application Specific Integrated Circuit (ASIC) chip. The tag antenna acts as electromagnetic power receiver and transmitter for the chip. For the purpose of energy conversion, the tag chip includes a charge capacitor that causes the tag chip to have largely reactive characteristic impedance, making the antenna more difficult to match with the tag chip than with a general radio frequency system of 50-Ω characteristic impedance. The electromagnetic power from the antenna is maximally delivered to the tag chip when the antenna has a conjugate impedance of the chip [2]. Since the energy interaction between the chip and antenna is one of the most important issues, a successful antenna design is determined by conjugate impedance match between both components [3]. Several papers have been published on RFID tag antennas, including meander antenna [4], slot antenna [5], folded dipole antenna [6], inductively coupled spiral antenna [7], etc. Some of them provide good concept for RFID tag antenna design aspects.

In this paper, we present a folded dipole antenna with a closed loop near the tag chip [8]. The required input resistance \((R_i)\) and reactance \((X_i)\) can be achieved separately by choosing appropriate geometry parameters. The proposed antenna can in particular find applications for the tag chips that require small resistance and large reactance. The design method, simulation results and read range performance measurement of this tag are included.

2. ANTENNA CONFIGURATION AND DESIGN METHOD
The configuration of the proposed folded dipole with a closed loop antenna is shown in Figure 1. The folded dipole part must be kept opening and it provides great freedom for impedance adjustment especially for the imaginary part, which is a very important feature for conjugate impedance matching design. This is achieved by tuning geometry parameters \(F_1\), \(F_2\) and \(F_3\) [6]. After obtaining satisfactory imaginary part, the closed loop was added to the previous folded dipole antenna and the geometry parameters \(L_1\) and \(L_2\) for the requirement conjugate impedance were tuned. The closed loop can pull down the impedance of the antenna especially for the real part. This feature makes the design approach to the actual impedance of the tag chip in the real cases.

We examined the proposed antenna with a real case where the chip impedance is \(22.0 - j130.0\). In our design, the operating frequency of the tag antenna was 925 MHz. The experimental model...
was made of copper-clad substrate with $\varepsilon_r = 4.4$ and the thickness $h = 1.6$ mm. The width of the copper line was $W = 1.44$ mm. After imaginary part was matched properly, the parameters of the folded dipole $F_1$, $F_2$, and $F_3$ were adjusted. Then the closed loop structure was added into the folded dipole and the parameters of the closed loop $L_1$ and $L_2$ were tuned to achieve conjugate impedance of the tag chip. The design and simulation of the structure are performed using Ansoft HFSS 10.

3. RESULTS OF SIMULATION AND IMPLEMENTATION

The simulated input impedance of the folded dipole antenna without a closed loop is shown in Figure 2. The impedance response increases with $F_3$, but decrease with $W$. The variation $R_i$ of is not significant, but $X_i$ is sensitive to the total length of the folded dipole. According to this property, we tuned $F_1$, $F_2$ and $F_3$ to obtain the required $X_i$ and disregard $R_i$ at this step.

![Figure 2: Input impedance of folded dipole with $F_3$ and $W$ as the parameters ($F_1 = 40$ mm, $F_2 = 20$ mm).](image)

Figure 3: Input impedance of presented antenna structure with $L_1$ and $L_2$ as the parameters ($F_1 = 40$ mm, $F_2 = 20$ mm, $F_3 = 25$ mm, $W = 1.4$ mm).

The simulated input impedance of the fixed parameters folded dipole antenna with a closed loop is shown in Figure 3. With the closed loop, it clearly reduces the input impedance, particularly to the $R_i$. The imaginary part, $X_i$ does not vary considerably with the parameters of the closed loop. The required impedance can be achieved easily by adjusting the parameters $L_1$ and $L_2$. Table 1 shows the parameters and simulated impedance for the target design.

<table>
<thead>
<tr>
<th>Strap impedance</th>
<th>Folded dipole (mm)</th>
<th>Closed loop (mm)</th>
<th>Antenna impedance</th>
<th>Maximum read range</th>
</tr>
</thead>
<tbody>
<tr>
<td>$22.0 - j130.0$</td>
<td>$F_1$</td>
<td>$F_2$</td>
<td>$F_3$</td>
<td>$L_1$</td>
</tr>
</tbody>
</table>

To verify the read range performance of the implementation using this antenna design, an RFID tag antenna with the parameters listed in Table 1 was made and tested. An RFID reader was set up to measure the read range performance of the RFID tag and the operation frequency band was 922–928 MHz. The radio power of the reader was approximately 750 mW and the gain of the linearly polarized reader antenna was 5.0 dBi, so the total transmit power is approximately 2.371 W EIRP (Effective Isotropic Radiated Power). The maximum read range of the RFID tag was approximately 3.5 m for the above specified test conditions. The result of the read range performance was also listed in Table 1.

According to the results of simulation and measurement, the input impedance $R_i$ and $X_i$ of the RFID tag antenna can achieve decoupled tuning with the proposed antenna configuration. In the other words, the parameters of folded dipole and closed loop can be tuned separately. Therefore,
the proposed antenna configuration is very useful for the RFID tag antenna design, particularly suitable for impedance requirement of small real part and large imaginary part.

4. CONCLUSION

In this paper, we realized a folded dipole with a closed loop for RFID tag antennas design. The closed loop makes impedance matching more easily especially when small resistance and large reactance of the antenna impedance are required. In addition, the closed loop serves as short circuit to DC current, so it can eliminate electrostatic discharge (ESD) from damaging the tag chip. The design method presented here can also be applied to various impedances of the commercial tag chips which operate at other frequency bands.

REFERENCES